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(71) Applicant: WESTINGHOUSE ELECTRIC CORPORATION [US/US]; 11 Stanwix Street, Pittsburgh, PA 15222-1384 (US).

(72) Inventor: MCQUIGGAN, Gerard; 4912 Lake Sharp Drive, Orlando, FL 32817 (US).

(74) Agents: PANIAN, Michael, G. et al.; Westinghouse Electric Corporation, 11 Stanwix Street, Pittsburgh, PA 15222-1384 (US).

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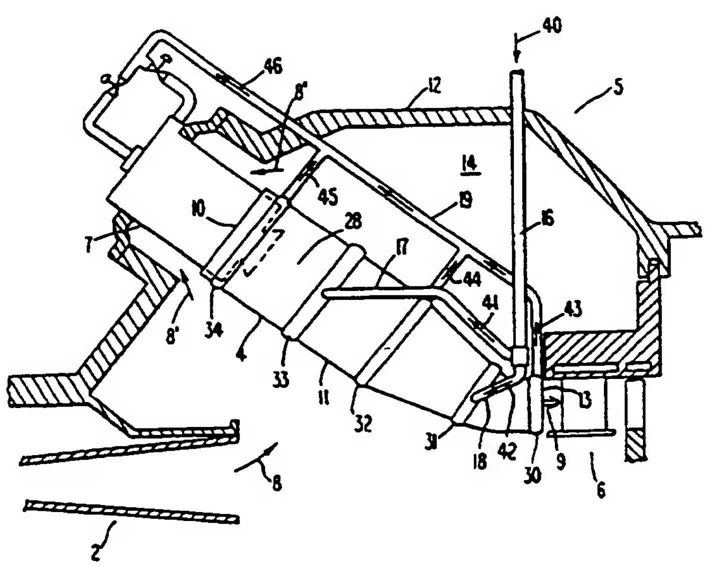

(57) Abstract

A combustor (4) having a wall (11) within and around which a plurality of cooling passages (24) are arranged. A supply pipe (16) brings a cooling fluid (40), such as gaseous fuel or compressed air, to a manifold (31, 33) that encircles the inlets of each of the holes. The manifold divides the cooling fluid in a number of small streams that flow axially toward a circumferentially extending array of outlets, thereby heating the fluid and cooling the combustor wall. In an embodiment in which the cooling fluid is compressed air, the passages discharge the heated compressed air to a chamber from which it enters the inlets of the combustors. In an embodiment in which the cooling fluid is gaseous fuel, a second manifold (30, 32, 34) that encircles the outlets collects the fuel and then directs it to a fuel nozzle for introduction into the combustion zone.

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GAS TURBINE REGENERATIVE COOLED COMBUSTOR

BACKGROUND OF THE INVENTION

The present invention relates to a combustor. More specifically, the present invention relates to a combustor for a gas turbine in which a fluid, such as gaseous fuel or compressed air, is used to cool the combustor wall and is then introduced into the combustor.

A gas turbine is comprised of three main components: a compressor section in which air is compressed, a combustion section in which the compressed air is heated by burning fuel, and a turbine section in which the hot compressed gas from the combustion section is expanded. To achieve maximum power output of the gas turbine, it is desirable to heat the gas flowing through the combustion section to as high a temperature as feasible. Consequently, the components in the turbine section exposed to the hot gas must be adequately cooled so that their temperature is maintained within allowable limits.

The combustion section typically includes a chamber in which a number of cylindrical combustors are disposed. A fuel nozzle disposed in each combustor introduces fuel which is then burned within the primary combustion zone of the combustor. Compressed air from the compressor flows into the chamber and is distributed to each of the combustors inlets so as to provide the air necessary for the combustion of the fuel in the primary combustion zone.

Traditionally, however, only a portion of the combustion air entered the primary combustion zone of the combustor, which operated in a fuel rich environment. A second portion of the combustion air entered the combustor downstream of the combustor inlet and provided the balance of the combustion air, as well as cooling air. Typically, this air was introduced through corrugations formed between adjacent sections of the combustor wall, thereby providing film cooling of the wall.

However, use of rich fuel/air mixtures in the primary combustion zone results in very high temperatures. Such high temperatures promoted the formation of oxides of nitrogen ("NOx"), considered an atmospheric pollutant. It is known that combustion at lean fuel/air ratios reduces NOx formation. However, achieving such lean mixtures requires that the fuel be widely distributed and very well mixed into the combustion air. Optimally, this can be accomplished by pre-mixing the fuel into the entirety of the combustion air prior to its introduction into the combustion zone. Therefore, it would be desirable to introduce all of the combustion air into the combustor inlet for use as combustion air in the primary zone.

Unfortunately, this approach does not allow for cooling of the combustor walls according to traditional cooling schemes. It is therefore desirable to provide a combustor in which the combustor walls are cooled despite the fact that no air, or at least substantially less air than that of the conventional scheme, is introduced into the combustor downstream of the combustor inlet.

SUMMARY OF THE INVENTION

Accordingly, it is the general object of the current invention to provide a combustor in which the combustor walls are cooled despite the fact that no air, or at least substantially less air than that of the conventional scheme, is introduced into the combustor downstream of the combustor inlet. Briefly, this object, as well as other objects of the current invention, is

accomplished in a combustor for heating compressed air by combusting a fuel therein, thereby producing hot compressed gas, that comprises (i) a liner having a wall having inner and outer surfaces, the inner surface of the wall forming a flow path for directing the flow of the hot compressed gas, (ii) a plurality of fuel passages formed within the wall extending between and substantially parallel to the inner and outer surfaces, and (iii) means for distributing the fuel to each of the passages prior to combustion thereof, whereby heat is transferred to the fuel from the wall, thereby heating the fuel and cooling the wall.

In a preferred embodiment of the invention, the wall is substantially cylindrical, and the passages are circumferentially arranged within and around the wall. In addition, the combustor has means for directing the heated fuel from each of the passages to the combustor zone for combustion therein.

Another embodiment of the invention comprises a gas turbine combustion system having a chamber having means for receiving a flow of compressed air and a combustor disposed in the chamber. The combustor has (i) means for receiving a fuel, (ii) a compressed air inlet in flow communication with the chamber, whereby the compressed air received by the chamber flows into the combustor and is combusted with the fuel so as to produce a flow of hot compressed gas, and (iii) a liner having a wall for containing the flow of hot compressed gas and a manifold. The wall has a plurality of passages formed therein. Each of the passages have an inlet and an outlet, the inlet of each of the passages being in flow communication with the manifold, and the outlets of each of the passages being in flow communication with the chamber. According to this embodiment, the combustion system also includes means for further pressurizing at least a portion of the compressed air received by the chamber and for directing the further pressurized air to the manifold, whereby the further pressurized air flows from the inlet of the passages to the

outlets of the passages, thereby absorbing heat from the wall, and then discharges into the chamber, where it enters the combustor compressed air inlet.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a longitudinal cross-section through the combustion section of a gas turbine incorporating the combustor of the current invention.

Figure 2 is a detailed view of the combustor shown in Figure 1.

Figure 3 is a is a cross-section of the combustor wall taken through line III-III shown in Figure 2.

Figure 4 is a is a cross-section of the combustor wall taken through line IV-IV shown in Figure 2.

Figure 5 is a cross-section of the combustor wall taken through line V-V shown in Figure 2.

Figure 6 is a cross-section of the combustor wall taken through line VI-VI shown in Figure 2.

Figure 7 is a view similar to Figure 1 showing another embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawings, there is shown in Figure 1 a longitudinal cross-section through the combustion section portion of a gas turbine. The gas turbine is comprised of a compressor section 2, the discharge diffuser portion of which is shown in Figure 1, that is driven by a turbine section 6, the first stage of which is shown in Figure 1, via a shaft (not shown). Ambient air is drawn into the compressor 2 and compressed. A portion 8′ of compressed air 8 produced by the compressor 2 is directed to a combustion system 5. The remainder of the compressed air 8 is used to cool the turbine section 6.

The combustion system 5 includes a shell 12 that forms a chamber 14. A number of combustors 4 are arranged in a circumferential array around the chamber 14. Each combustor 4 is comprised of a liner formed by a wall 11, shown in Figure 3. As shown in Figures 2 and 3, the inner surface of the wall 11, which may have a thermal barrier

coating, forms a containment that encloses the combustion zone 28 and directs the flow of hot combustion gas 9 from the combustion zone to a combustor outlet 13. In the front portion of the combustor 4, the wall 11 is approximately cylindrical and defines an axial centerline 15 for the combustor. However, in its downstream portion, the wall 11 undergoes a transition into the arcuate outlet 13 that, when combined with the outlets of the other combustors, it forms the annular inlet to the turbine 6. A number of cooling fluid manifolds 30-34 encircle the wall 11.

As shown in Figure 1, a fuel pre-mixing nozzle 7 is disposed within the inlet 10 of each of the combustors 4 and introduces fuel 46 into the combustor. According to the current invention, the fuel 45 is preferably a gaseous fuel, such as natural gas, that has been pre-heated, as discussed in detail below. In the combustors 4, the fuel 46 is burned in the compressed air 8, thereby producing the hot compressed gas 9.

The hot compressed gas 9 produced by the combustor 4 is directed to the turbine 6 where it is expanded, thereby producing shaft horsepower for driving the compressor 2, as well as a load, such as an electric generator. The expanded gas produced by the turbine 6 is exhausted, either directly to the atmosphere or, in a combined cycle plant, to a heat recovery steam generator and then to atmosphere.

According to the preferred embodiment of the current invention, all of the compressed air 8' that is introduced into the flow path defined by the combustor 4 enters through the inlet 10 and forms the combustion air in which the fuel 46 is burned in the combustion zone of the combustor. Preferably, no compressed air is introduced into the hot combustion gas 9 downstream of the combustor inlet 10 and, therefore, downstream of the combustion zone. As a result of the large amount of combustion air 8', the combustion temperature and, therefore, the NOx production is minimized. Nevertheless, by utilizing the principles of

the current invention, the combustor wall 11 is adequately cooled as discussed below.

As shown in Figures 3-6, according to the current invention, a large number of small passages, preferably several hundred, are circumferentially arranged around and within the combustor wall 11. Preferably, the passages extend substantially parallel with the inner and outer surfaces 38 and 39, respectively, of the wall 11. According to the current invention, the passages extend axially, and, most preferably, parallel to the axial centerline 15 of the combustor 4 and parallel to each other along substantially the entire length of the combustor 4. Figure 3 shows the portions 24 of each of the passages that extend between manifolds 33 and 34. As shown in Figures 5 and 6, other portions of the passages extend between the remaining manifolds -- i.e., portions 25 of the passages extend between manifolds 32 and 33, portions 26 of the passages extend between manifolds 31 and 32, and portions 27 of the passages extend between manifolds 30 and 31.

Preferably, the passages are formed by milling continuous channels in the surface of a plate that is subsequently bonded to the surface of another plate. The plate laminate is then formed into the wall 11. Although in the preferred embodiment continuous passages are used, intermittent passages that start and stop at each manifold could also be utilized.

As shown in Figures 5 and 6, small passages 60-63 connecting with the passages 24-27 extend radially outward with respect to the combustor axis 15 so as to form circumferentially extending rows of inlets 50 and outlets 51 for the passages on the outer surface 39 of the combustor wall 11.

As shown in Figure 2, in the preferred embodiment of the invention, gaseous fuel 40 from a fuel supply is directed by piping 16 to each of the combustors 4. The fuel 40 is then split into two streams 41 and 42 by pipes 17 and 18, respectively. The pipe 17 directs the fuel 41

to the manifold 33, which distributes it circumferentially around the wall 11 to the inlets 50 of the passages 24 and 25, as shown in Figures 4 and 5. From the inlets 50, the fuel 41 is divided into two sets of small streams 41′ and 41", as shown in Figures 2 and 5. The small streams of fuel 41′ flow axially upstream through passages 24 toward the manifold 34. The small streams of fuel 41" flow axially downstream through passages 25 toward the manifold 32. In so doing, the fuel 41 absorbs heat from the wall 11, thereby cooling the wall and pre-heating the fuel.

In a similar fashion, the portion 42 of the fuel 40 is directed by pipe 18 to manifold 31. From manifold 31, the fuel 42 is divided into two sets of small streams. Streams 42′ flows axially upstream through passages 26 toward manifold 32, whereas streams 42" flow axially downstream through passages 27 toward manifold 30.

The heated streams of fuel 43, 44, and 45 from the manifolds 30, 32 and 34, are by directed by pipes 20, 21 and 22, respectively, to a common header 19. The header pipe 19 directs the combined flow of heated fuel 46 to the fuel nozzle 7 for introduction into the combustion zone within the combustor 4, as shown in Figure 1. Thus, the fuel 40 serves to cool the walls 11 of the combustor 4 so that, preferably, all of the combustion air 8′ can be introduced at the combustor inlet 10 for use in the primary combustion zone. This ensures that the combustion zone will receive a lean, well mixed fuel/air mixture, thereby minimizing the generation of NOx. In addition, the heated absorbed by the fuel 40 is returned to the combustor 4 with the heated fuel 46, so that essentially no energy is lost from the thermodynamic cycle as a result of cooling the combustor wall 11.

Figure 7 shows another embodiment of the current invention is which combustion air is used to cool the combustor wall, yet all of the compressed air 8′ still enters the combustor 4′ through the inlet 10 for combustion with the fuel 40′ and 40". In this embodiment, a portion

80 of the compressed air 8 that enters the chamber 14 is bled from the chamber via piping 70. The piping 70 directs the compressed air to a boost compressor 71, which further compresses it. The further compressed air is then directed back through the chamber 14 by piping 72 to the combustor 4'.

Piping 73 and 74 divides the further compressed air into two streams 82 and 83. Air stream 82 is directed by piping 74 to a manifold 90, which is similar to the manifold 33, shown in Figure 4. From the manifold 90, the compressed air 82 is divided into two groups of streams 82' and 82" that flow through passages in the combustor wall 11, as previously discussed. Streams 82' flow axially upstream through passages 24, as previously discussed, toward a circumferentially extending row of outlets 92, similar to the outlets 51 shown in Figure 5. However, in this embodiment, there is no manifold encircling the outlets so that the streams of heated air 84 are discharged back into the chamber 14.

Streams 82" flow axially downstream through passages 25 toward a second circumferentially extending row of outlets 93, similar to the outlets 51 shown in Figure 6. Once again, the streams of heated air 85 are discharged back into the chamber 14.

Similarly, air stream 83 is directed by piping 73 to a manifold 91, which is similar to the manifold 31, shown in Figure 6. From the manifold 91, the air 83 is divided into streams 83' and 83" that flow upstream toward the row of outlets 93 and downstream toward a row of outlets 94, respectively, after which this heated air is also discharged back into the chamber 14. Thus, although this embodiment relies on air, rather than fuel, for cooling, all of the compressed air can be still be directed through the combustor inlet 10 to ensure that a lean fuel/air ratio is achieved in the combustion zone 28. In addition, the heat absorbed by the cooling air is returned to the combustor 4'.

The present invention may be embodied in other specific forms without departing from the spirit or essential attributes thereof and, accordingly, reference should be made to the appended claims, rather than to the foregoing specification, as indicating the scope of the invention.

CLAIMS:

1. A combustor for heating compressed air by combusting a fuel therein, thereby producing hot compressed gas, said combustor comprising:

a) a liner formed by a wall having inner and outer surfaces, said inner surface of said wall forming a flow path for directing the flow of said hot compressed gas, a plurality of fuel passages formed within said wall extending between and substantially parallel to said inner and outer surfaces; and

b) means for distributing said fuel to each of said passages prior to combustion thereof, whereby heat is transferred to said fuel from said wall, thereby heating said fuel and cooling said wall.

2. The combustor according to claim 1, wherein said combustor defines an axial center line thereof, said passages extending substantially parallel to said axial center line.

3. The combustor according to claim 2, wherein at least a portion of said wall is substantially cylindrical, said passages circumferentially arranged within and around said cylindrical portion of said wall.

4. The combustor according to claim 1, wherein said wall encloses a combustion zone, and further

comprising means for directing said heated fuel from each of said passages to said combustor zone for combustion therein.

5. The combustor according to claim 4, wherein said means for distributing said fuel to each of said passages comprises a first manifold in flow communication with each of said passages.

6. The combustor according to claim 5, wherein said means for directing said heated fuel from each of said passages to said combustion zone comprises a second manifold in flow communication with each of said passages.

7. The combustor according to claim 6, wherein said first and second manifolds each encircle at least a portion of said wall.

8. The combustor according to claim 6, further comprising a fuel nozzle for discharging said heated fuel into said combustion zone, said second manifold being in flow communication with said fuel nozzle.

9. The combustor according to claim 6, wherein said means for directing said heated fuel from each of said passages to said combustion zone further comprises a third manifold in flow communication with each of said passages, said first manifold being disposed between said second and third manifolds.

10. The combustor according to claim 9, wherein said passages have:

a) means for directing a first portion of said fuel flowing through said passages from said first manifold to said second manifold in the same direction as the flow of said hot compressed gas through said flow path;

b) means for directing a second portion of said fuel flowing through said passages from said first manifold to said third manifold in the direction counter to the flow of said hot compressed gas through said flow path.

11. A gas turbine combustion system, comprising:

a) a chamber having means for receiving a flow of compressed air from a first compressor;

b) a combustor disposed in said chamber, said combustor having:

(i) means for receiving a fuel,

(ii) a compressed air inlet in flow communication with said chamber, whereby said compressed air received by said chamber flows into said combustor and is combusted with said fuel, thereby producing a flow of hot compressed gas,

(iii) a liner having a wall for containing said flow of hot compressed gas and a manifold, said wall having a plurality of passages formed therein, each of said passages having an inlet and an outlet, said inlet of each of said passages being in flow communication with said manifold, said outlets of each of said passages being in flow communication with said chamber;

c) means for further pressurizing at least a portion of said compressed air received by said chamber and for directing said further pressurized air to said manifold, whereby said further pressurized air flows from said inlet of said passages to said outlets of said passages thereby absorbing heat from said wall and then discharges into said chamber where it enters said combustor compressed air inlet.

12. The combustion system according to claim 11, wherein said combustor defines an axial center line thereof, said passages extending substantially parallel to said axial center line.

13. The combustion system according to claim 11, wherein at least a portion of said wall is substantially cylindrical, said passages circumferentially arranged within and around said cylindrical portion of said wall.

14. The combustion system according to claim 11, wherein said means for further pressurizing said compressed air and for directing said further pressurized air to said manifold comprises a second compressor.

15. The combustion system according to claim 14, wherein said means for further pressurizing said compressed air and for directing said further pressurized air to said manifold further comprises a conduit having an inlet in flow communication with said chamber, said second compressor disposed in said conduit.

16. A combustor comprising:

a) a substantially cylindrical wall defining an axis thereof, first and second pluralities of axially extending passages formed in said wall and distributed circumferentially there-around; and

b) a first manifold having means for receiving a fluid, said first manifold in flow communication with said first and second pluralities of passages, said first plurality of passages extending from said first manifold in a first axial direction, said second plurality of passages extending from said first manifold in a second axial direction opposite to said first axial direction, whereby said fluid received by

said manifold flows through said first and second pluralities of passages in opposite directions.

17. The combustor according to claim 16, further comprising second and third manifolds having means for discharging said fluid received by said first manifold, said second manifold in flow communication with said first plurality of passages, said third manifold in flow communication with said second plurality of passages, whereby said fluid flowing through said first and second passages in opposite directions is collected by said second and third manifolds, respectively.

18. The combustor according to claim 17, wherein said first, second and third manifolds encircle said wall.

19. The combustor according to claim 17, wherein said fluid is a fuel, and further comprising a fuel nozzle for introducing said fuel into said combustor and means for directing said fuel from said second and third manifolds to said fuel nozzle.

20. The combustor according to claim 16, wherein said fluid is compressed air.

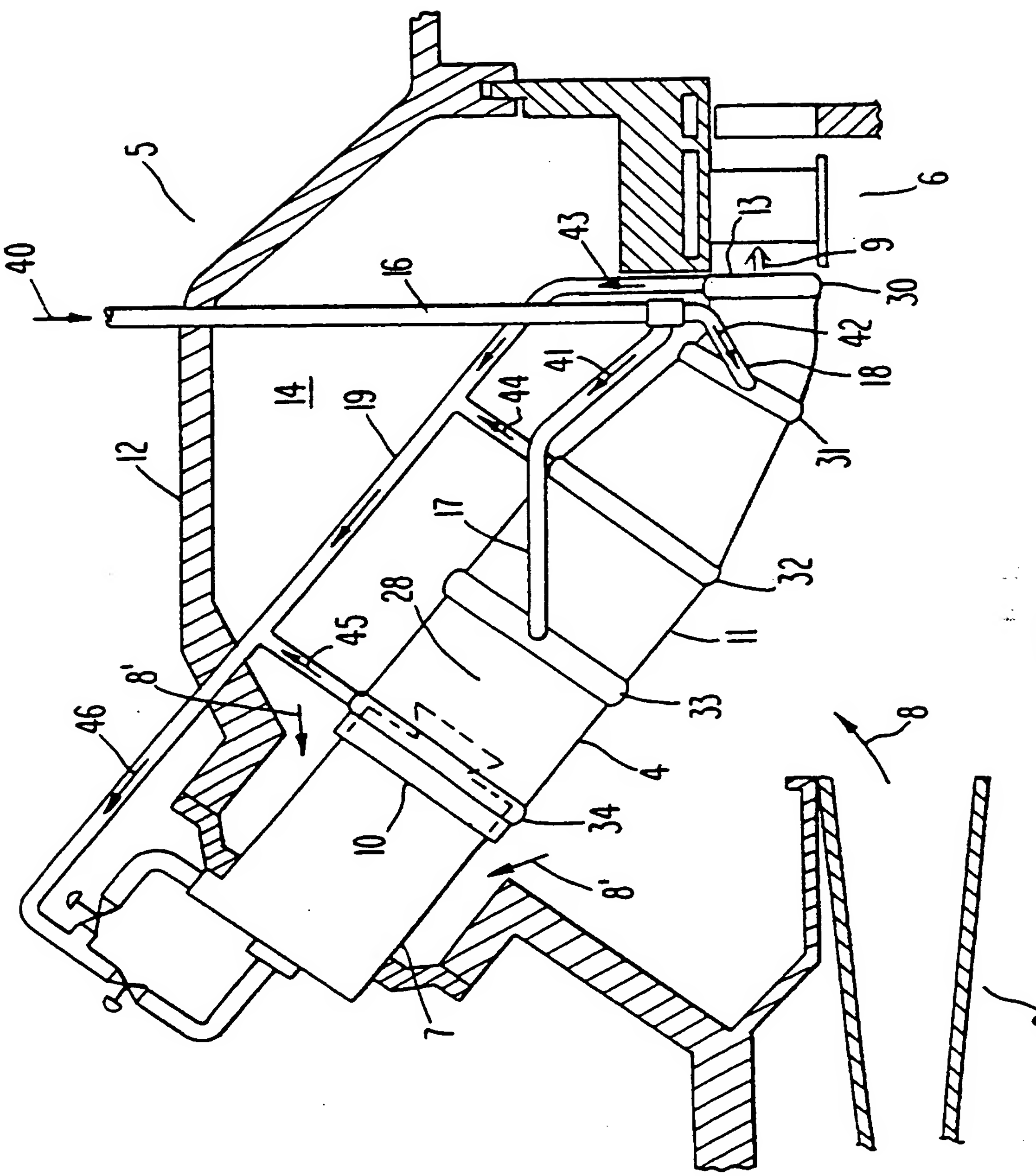
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Fig. 1

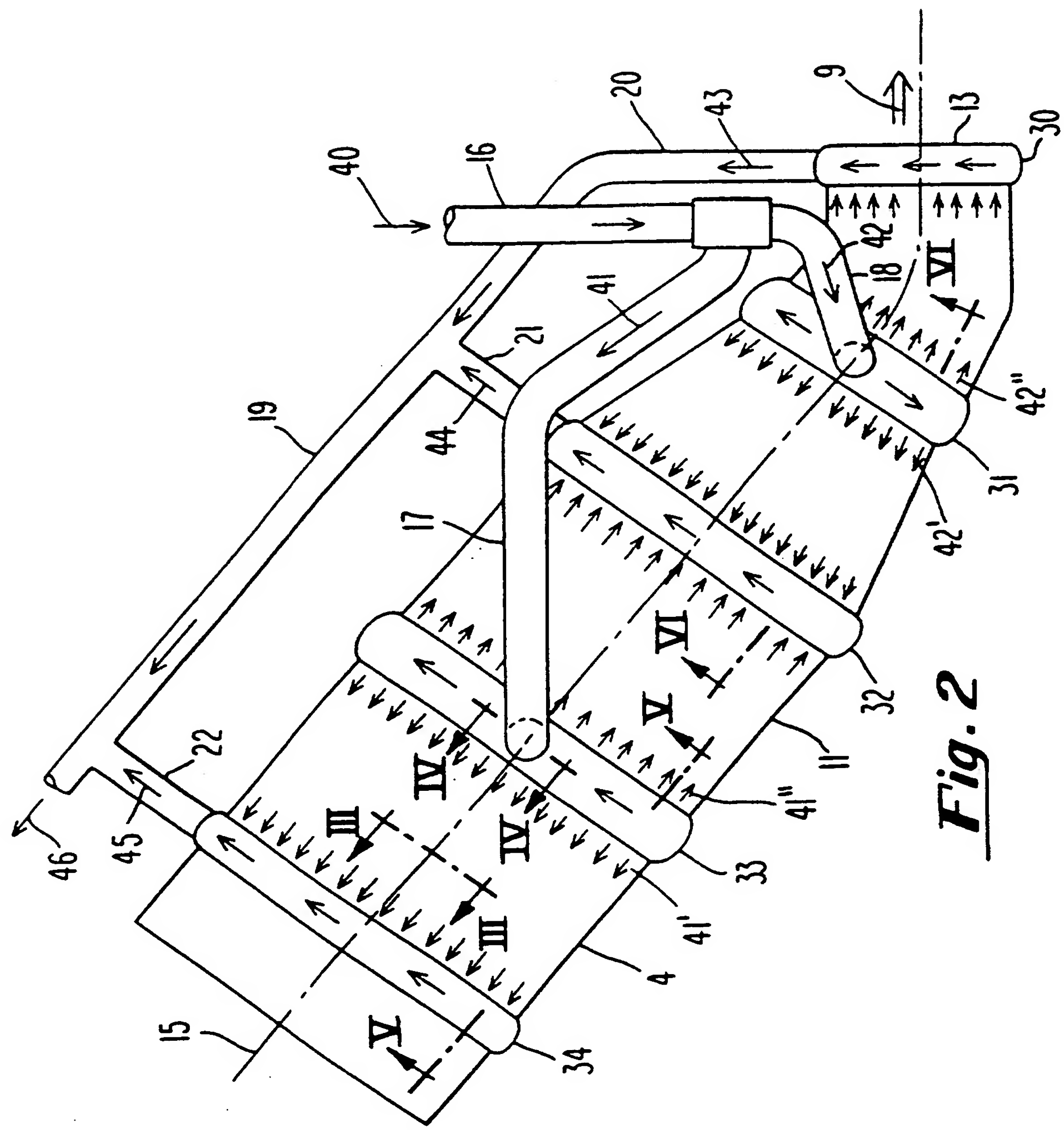
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Fig. 2

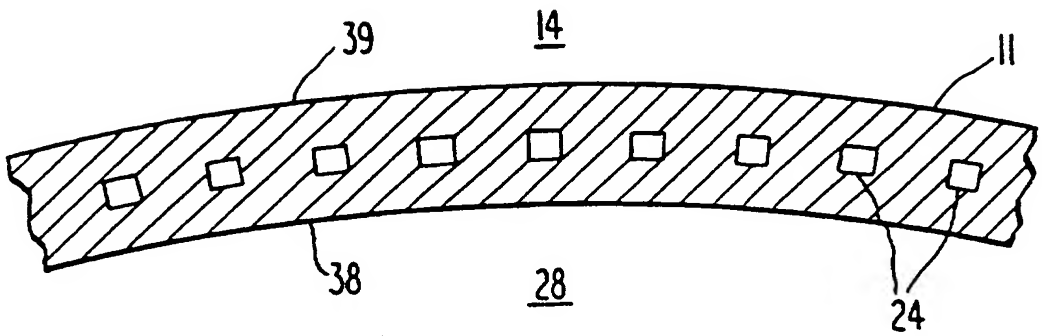

Fig. 3

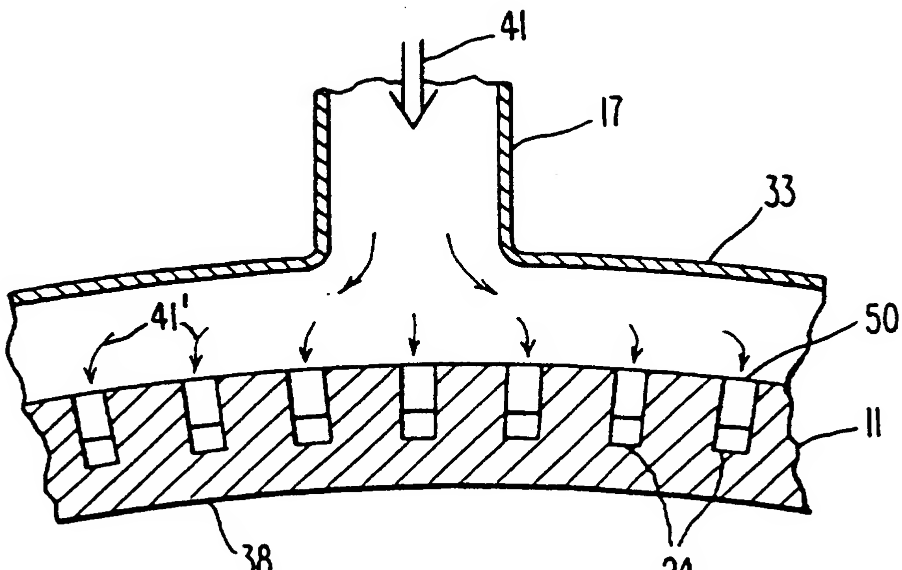

Fig. 4

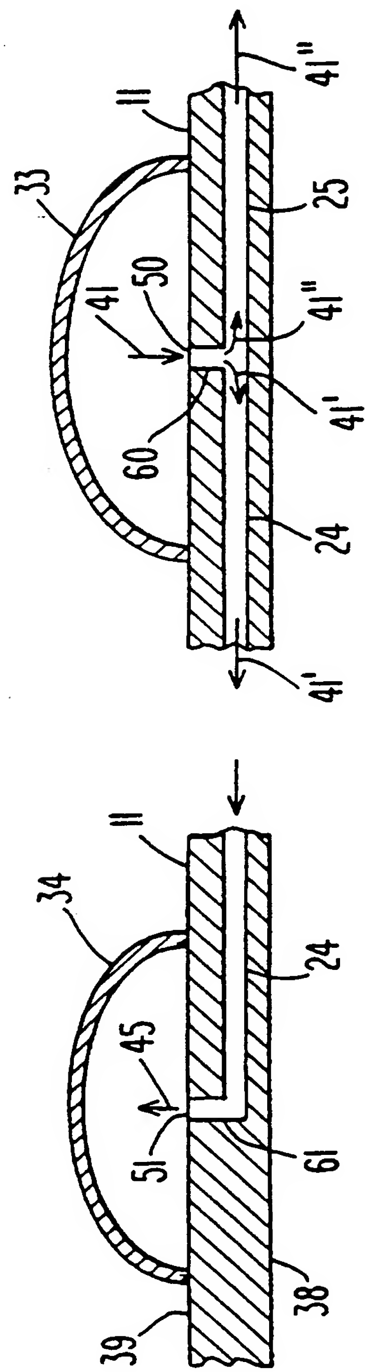
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Fig. 5

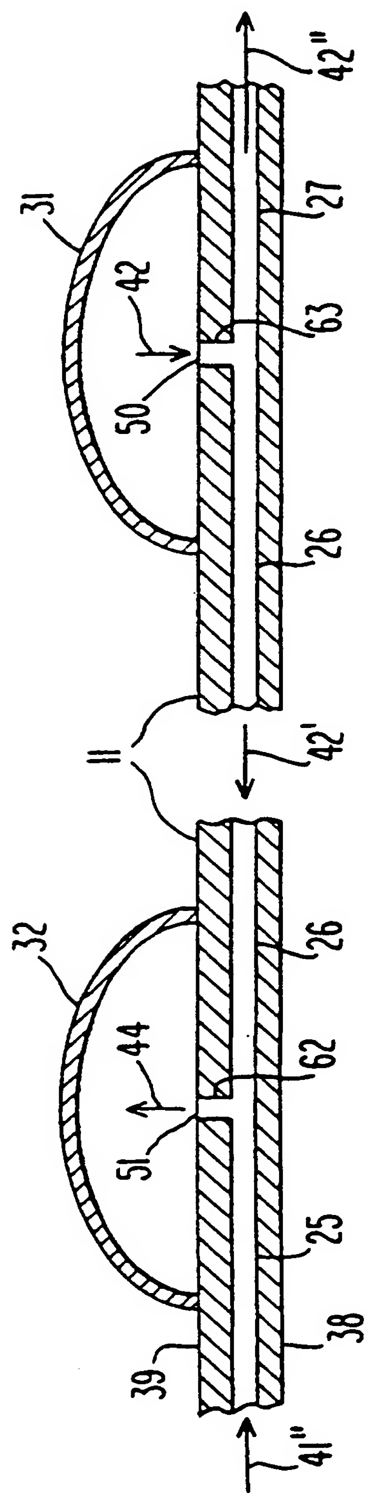
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Fig. 6

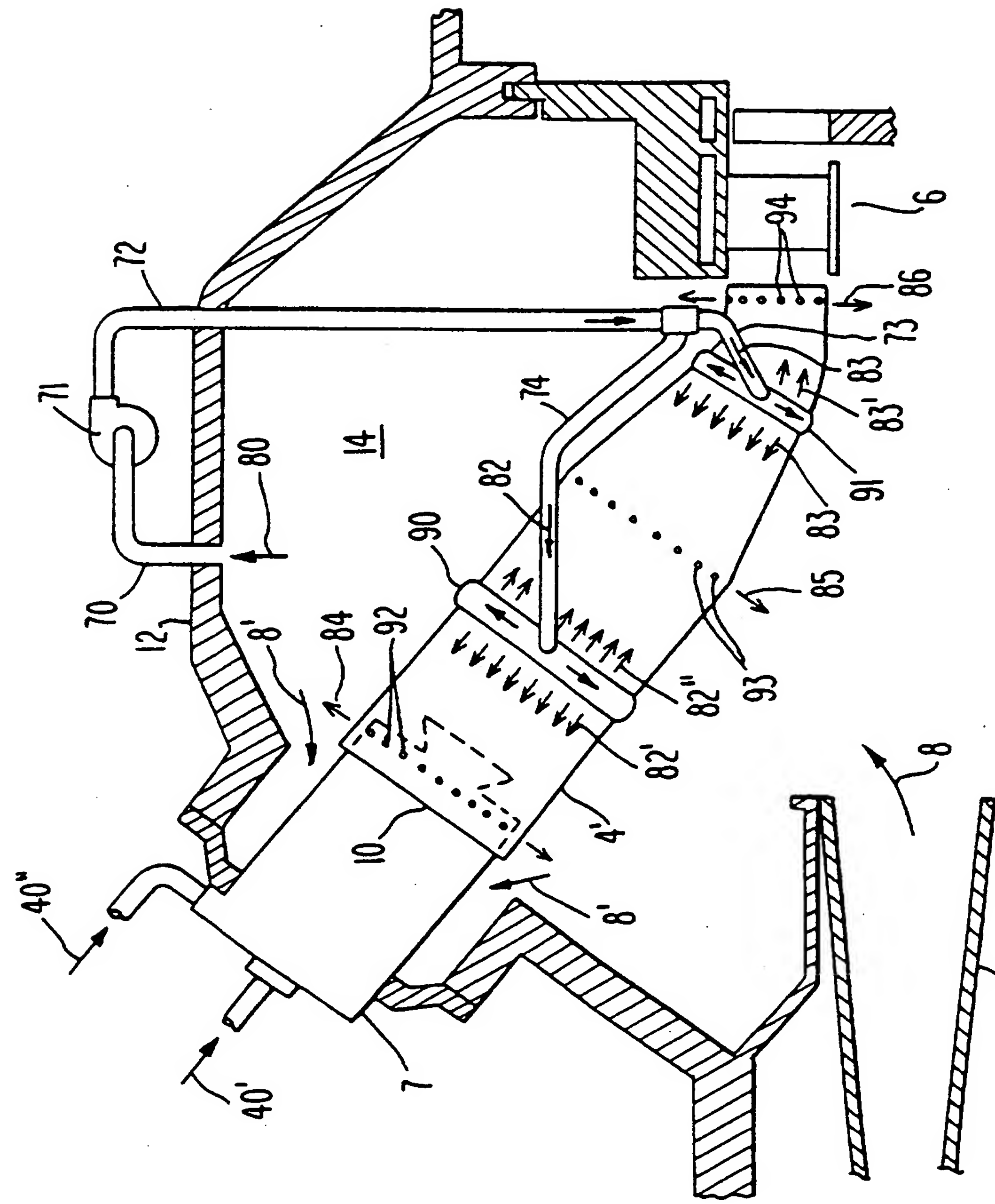
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Fig. 7

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 96/13749

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 F02C7/224 F23R3/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 F02C F23R F02K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X Y	US,A,2 716 330 (S. WAY) 30 August 1955 see the whole document	16,20 11-13
X	FR,A,2 250 899 (MESSERSCHMITT BOELKOW BLOHM) 6 June 1975 see figures	1-10, 16-19
X	US,A,3 099 909 (P.NEWCOMB) 6 August 1963 see the whole document	1,4-6, 8-10
X	GB,A,2 119 447 (KERSHAW H A) 16 November 1983 see abstract; figure 4	1-3, 11-13

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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1

Date of the actual completion of the international search	Date of mailing of the international search report
10 December 1996	18.12.96
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Argentini, A

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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PCT/US 96/13749

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GB-A-2119447	16-11-83	NONE		
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